

Black arrow indicate dip of geologic layers away from the Black Hills uplift.

Blue are indicates regional groundwater flow down dip and then around the south end of the Black Hills.

# Groundwater geochemistry

- Uranium remains relatively insoluble (40 ppb or less with little to no dissolved oxygen in the current groundwater)
- Uranium daughter products (like radon and radium) are greatest in the uranium ore deposits
- Roll fronts are not currently forming



# Summary

- Yes, we can simulate the full evolution of roll-front formation, current conditions, ISR mining, restoration, and longer-term transport
- Yes, the simulations can be done quantitatively and in three dimensions
- Yes, reactive transport modeling can be used as a tool to test restoration schemes and the influence on longer-term geochemistry

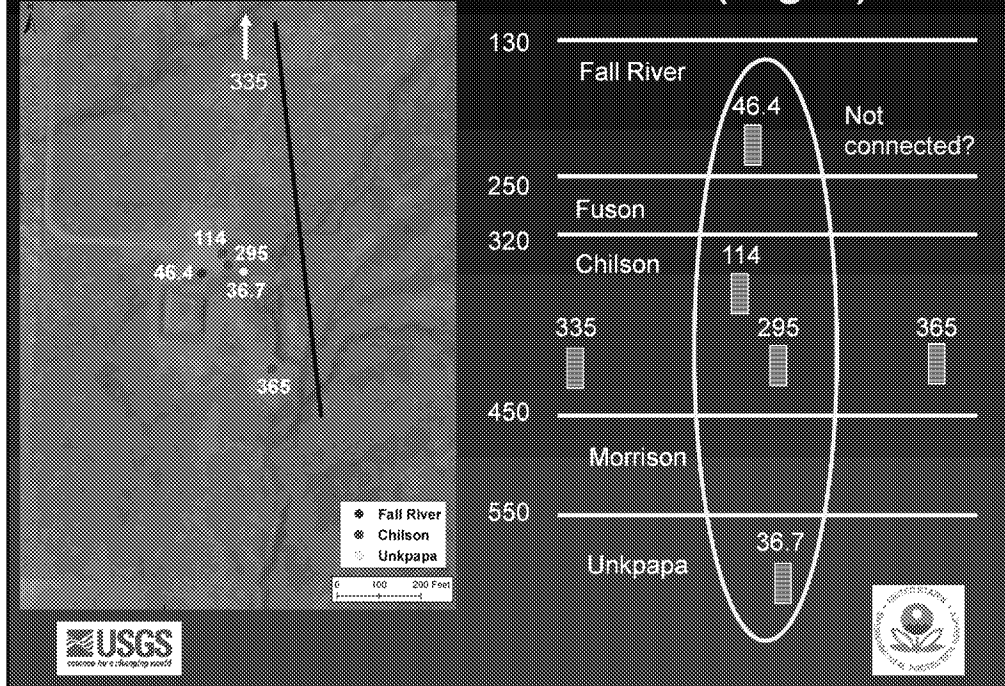


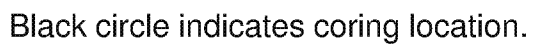
# Groundwater Geochemistry

- Field parameters (temp., pH, pe, DO, cond.)
- Cations and dissolved metals
- Anions (sulfate, chloride, fluoride)
- Uranium isotopes and uranium concentration
- Dissolved organic carbon
- Iron species
- Tritium
- Water isotopes ( $^{18}\text{O}$  and D)
- $^{34}\text{S}$
- $^{14}\text{C}$  – 6 samples sent on Jan. 10



# Burdock Area Calcium (mg/L)

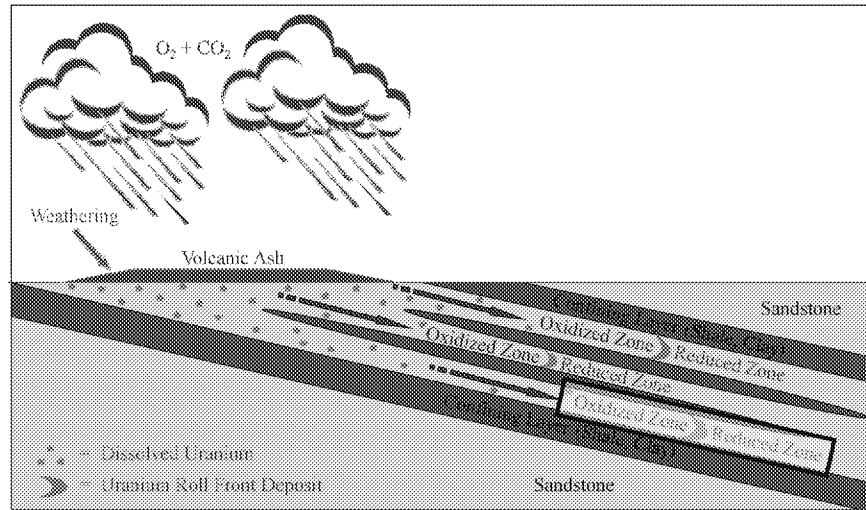






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# Roll-Front Formation





## Take Home Points

- Pyrite is potentially the key to removing uranium (modeled reducing conditions)
- Calcite is potentially the key to buffering acidity
- With these minerals present, get an iron, sulfate, calcium, carbonate: "plume"
  - Not toxic
  - Already relatively high concentrations in some locations
  - What levels are acceptable?
- Increase in these elements depends on the amount of oxygen left in the mining zone

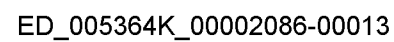


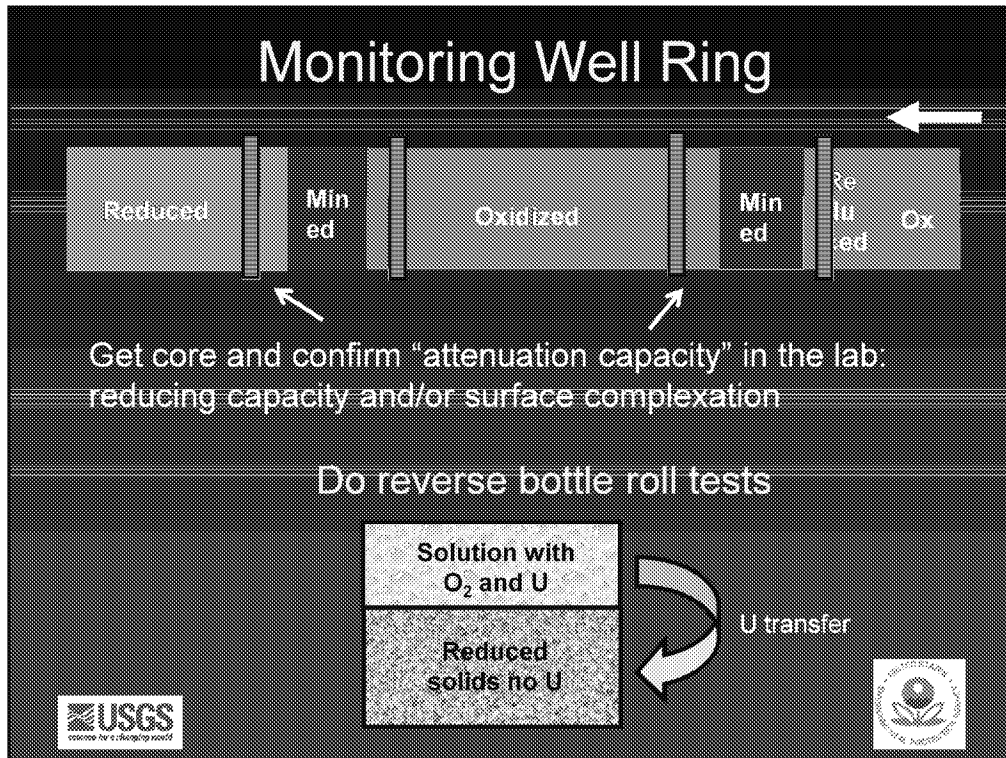
Last point is the focus for some restoration efforts to add reductants that might re-establishing reducing capacities.

## Other Things to Consider

- Other reductants (organic carbon)
- Surface complexation (uranium sorption on iron hydroxides)
- Dispersion (scale dependent dilution)
- This presentation is “worst case” scenarios







For mining zones, companies often to a batch test with ore and lixiviant in a bottle that is constantly rotated to determine uranium recovery (bottle roll tests).

A reverse bottle roll test would take reduced material with no uranium ore and add uranium rich water to see how much uranium would be left in solution after mixing for a certain period of time.